INTERNATIONAL DESIGN CONFERENCE - DESIGN 2012
Dubrovnik - Croatia, May 21 - 24, 2012.

DESIGN 2012

PARTBOOK – A SOCIAL MEDIA APPROACH FOR CAPTURING INFORMAL PRODUCT KNOWLEDGE

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Keywords: PartBook, Social Media, Informal Product Knowledge, IPK, Informal Engineering Communication, IEC

1. Introduction

During engineering activities, a great deal of data and information (D&I) is communicated through informal channels. Gopsill et al's [2011] review of the current capability of the Product Lifecycle (PL) information systems infrastructure highlights that there are no systems that currently capture, manage and share the full scope of informal engineering communication generated over the PL. Informal engineering communication often contains the rationale behind the decisions made and the insights/conclusions drawn from the aggregation of information within the PL [Huet et al., 2007]. Ellis and Haugan [1997] highlight that engineers often seek information through informal channels to complete their task and this is further supported by Brown and Duguid [2000], who reveal that there is a large gap in how a task is described in a manual and what happens in reality. It is therefore argued that formal process-driven systems cannot cater for every situation or task and is most likely the reason why engineers make use of informal channels to share knowledge.

Eckert and Boujut [2003], Boujut and Blanco [2003], and Delinchant et al. [2002] show that design communications often occur around an artefact (also known as an intermediary or boundary object), which aids the communication and co-operation between engineers across multiple disciplines. Example artefacts include, sketches, modelling code, CAD models, calculations, simulation set-up/results, product testing, the products and parts. For this reason, it is contended that in order to capture informal engineering communications and what can be thought as Informal Product Knowledge (IPK), there is a need to consider both the intermediary object and the associated communication. Basic examples are illustrated in figure 1. Example 1 shows a discussion being had on a bike sketch, example 2 on the maintenance of a torn tyre and example 3 looking at setting up some simulation code.

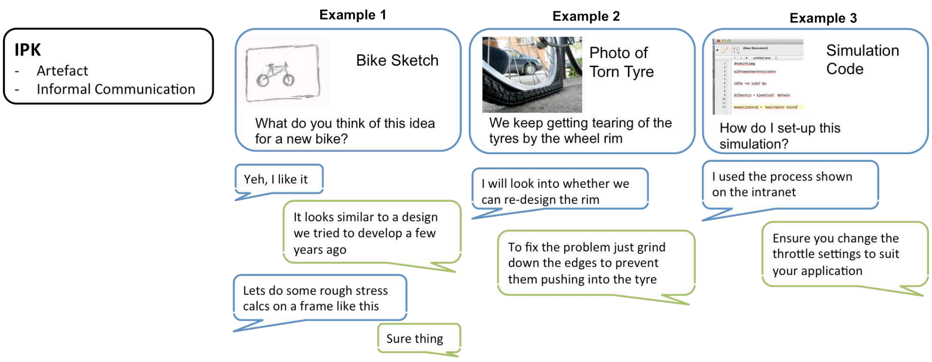

Figure 1: Basic Examples of Informal Product Knowledge

It is argued that the real-time capture, management and sharing of IPK has great potential in aiding engineers to perform their activities and to receive the right information for them to be able to draw the appropriate conclusions/insights and make well-informed decisions. While there are some approaches such as DREd [Bracewell et al., 2004], these do not support real-time engineering work and only focus upon either a particular phase, individual or perspective such as rationale capture. Enabling an open environment by which these communications take place could enable engineers from across the PL to contribute to any of the discussions. This would potentially increase the engineer-to-engineer communication to provide the right information at the right time as they have greater understanding of the context and other engineers' needs. Further, it has been shown that increased communication is present during the design of a successful product [Griffin and Hauser, 1992, Dougherty, 1987].

Additionally, the capture and management of IPK could enable re-use through the ability for engineers to learn from past communications and therefore may reduce the re-occurrence of work during re-design/variant design. It may also enable the company to create and build upon a company knowledge base. Having this base allows the potential for Knowledge Discovery (KD) techniques to be applied to the captured artefacts and communications being shared and thus may be able to provide useful information on the knowledge sharing activities within the company. It could be envisaged that analysis of the patterns of activity could lead to identification of problems arising in the PL, lessons not being learned, new lessons being learned and PL progress (for example, the stage at which a new product has reached in its development). It has been shown that organisational memory can impact the performance and creativity behind new product development [Moorman and Miner, 1997]. Thus, the above-described affordances could all aid in improving the organisational memory of the company. Finally, capturing and managing IPK could help to integrate and complete the overall design record.

Liebowitz and Wright [1999] state that achieving knowledge sharing is 'power'. This is further confirmed by Bender and Fish [2000], who state that knowledge sharing is critical to competitive advantage. Finally, the ability to share IPK could aid the training of new engineers through their absorption of the knowledge and being able to have experienced engineers from across the PL sharing the right information with them.

However, whilst there is great potential in capturing, managing and sharing IPK across the PL; however, there are some key challenges to overcome to achieve this. Lowe et al. [2004] highlights the issue that each engineer requires different types of data and information (D&I) and that informal channels transmit a great variety of D&I, thus there is a need to understand the scope of IPK within the PL. This is further enforced by Leckie et al. [1996], who raise the issue that a professional's information requirements are heavily influenced by their role-task relationship and is almost always different to another professional. Therefore, achieving awareness of information and creating the right connection for knowledge sharing (i.e. ensuring the question is answered by the right engineer/s) poses a significant challenge. Sharratt and Usoro's [2003] research on knowledge sharing within communities of practice mentions the fact that the methods by which knowledge is shared can influence the information captured. Thus, understanding how the capture process will affect the use/re-use and communication generation is an additional challenge. Al-Rawas et al. [1996] sums up the challenges facing knowledge sharing and describes three major communication barriers:

1. The ineffectiveness of the current communication channels
2. The restriction on expressiveness imposed by notations
3. The social and organisational barriers

To address these challenges this paper reports on the creation of a social media approach for the capture, management and sharing of IPK. The paper begins with a summary of the underlying framework currently under development for the capture, management and sharing of IPK objects and then discusses in detail the social media model and demonstrator system being used for evaluation and validation.

2. Towards a Framework for the Capture, Management and Sharing of IPK

This section details the key areas of the underlying framework for the capture, management and sharing of IPK objects, with particular focus on the requirements for such a framework.

2.1 Artefact Capture

It has been previously discussed that almost all informal engineering communications revolve around an artefact [Carlile, 2002, Hendersen, 1991, Subrahmanian et al., 2003]. Thus, it can be seen that there is a need to capture information regarding and generate a representation of the artefact to best support informal communications across the PL. Capturing information about the artefact offers a high degree of additional contextualisation that boundary objects afford and it has been shown that this visual aspect aids engineers use and re-use of the information [Heisig et al., 2010]. For the case of this research, the information representation of the artefact will come in the form of an image (e.g. photo or screenshot) as this enables the capture of almost any artefact such as, sketches, CAD files, simulation results, reports and annotated drawings. In addition to the capture of the representation of the artefact, there is also a need to record the type of artefact being capture alongside the contextual element of the artefact. This contextual element is to enable the engineer to highlight 'what they are trying to tell us?' Finally, although there is an artefact upon the initiation of a communication, there is also evidence to suggest that additional artefacts can be added during and upon concluding a communication episode (i.e. picture of an punctured tyre at the start and a picture of the repaired tyre at the end).

2.2 Communication Evolution and Context Capture

In developing the framework, there has been a need to be able to both enhance and manage the evolution of the knowledge sharing process. Review of the literature has revealed that there are a number of reasons why an engineer wants to initiate a communication [Aurisicchio et al., 2010, Wasiak et al., 2011]. This initiation can then have a profound impact on how the communication evolves. Example initiators include *presenting an idea*, *asking for help*, *highlighting an issue* and *asking for confirmation*. Alongside this, during the creation of an IPK there is a need to capture multiple-perspectives of the communication to provide additional contextualisation and for search and retrieval [Weiser and Morrison, 1998]. Engineers have been shown to seek for information through many perspectives including, product, part, lifecycle phase and organisational structure.

As engineers partake in the communication, research has shown that there is a need to capture the context behind the response being made if the communication is going to occur within a computer mediated environment [Hertzum and Pejtersen, 2000, Smith et al., 2000]. Example types of response include *presenting an opinion*, *talking from experience* and *providing guidance*. In addition, the communication requires the ability to allow multiple perspectives within the channel itself. Multi-threading within the communication is seen as a necessity within the computer-mediated communication when considering the multi-disciplinary nature of engineering [Eckert and Stacey. 2001, Baird et al., 2000]. Capturing the context of the response and additionally imposing loose rules such as a text limitation and directing the response to a particular part of the conversation are aimed at providing concise direct responses and therefore avoid *'waffle'* [Perry and Sanderson, 1998].

Upon the conclusion or completion of a communication episode, there is a need to capture the context behind the type of conclusion being made, which is highly dependent upon the initiating context. For example, proposing an idea may lead to a *good idea being pursed*, *a good idea not being pursed*, a *non-plausible idea* or *an idea that may have already been conceived*. Capturing the context behind the communication is aimed at improving both the use and re-use potential. It also enables us to understand how engineering communications evolve across the PL.

2.3 Re-use through hindsight

As the proposition of this research is to capture communications that are occurring across the lifecycle, there is a need to understand how these could be re-used. The literature shows that engineers often refer to previous designs and information to aid in the future tasks [Vijaykumar and Chakrabarti, 2008]. Thus, it is proposed to enable hindsight, which provides the ability for engineers to refer back to past communications and to highlight areas of re-use alongside the context behind the re-use of the communication such as, *amending a past communication*, *highlighting redundant information* and *highlighting a re-used element*.

2.4 Managing and Sharing IPK objects

Informal engineering communications can be said to have no pre-defined structure between one another: A communication can exist entirely separately to all other communications. However, there is strong evidence to suggest that there are links between communications, such as referring back to a previous communication (i.e. I spoke to Joe and…), the need to group communications relating to tasks or expert groups to enable the receivership of the right communication to the right engineers and personal bookmarking to enable engineers to use their own social knowledge to highlight communications for others (i.e. Joe would know about this) [Milne and Leifer, 2000, Zipperer, 1993]. Thus, the framework enables these links to be made in order for communications to be better managed and shared throughout the PL and for the system to be pro-active in highlighting the right communications for the right engineers.

2.5 A Framework for the Capture, Management and Sharing of IPK

In order to satisfy these requirements, a framework has been created to semi-structure and manage the evolution of an IPK object. Five key elements are shown in figure 3 and include:

1. **Artefact Classification:** To capture a representation of the artefact alongside additional contextual information regarding the type and reasoning for the artefact.
2. **Product/Part & PL+Organisational Classification:** To capture the multiple perspectives used within the engineering domain to enable use and re-use of IPK objects.
3. **Communication Classification:** To capture the context behind the communication elements and semi-structure the evolution of the communication from its initiation to its conclusion.
4. **Hindsight Classification:** To capture the context behind the re-use of elements within an IPK object.
5. **Managing and Sharing Criteria:** To provide the mechanisms for search, retrieval, enable the links and relationships between IPK objects, and the ability to push the right information to the right engineers.

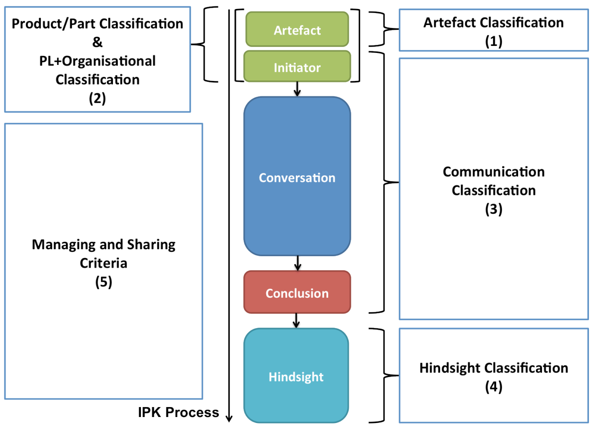

Figure 3: Brief Overview of a Framework for the Capture, Management and Sharing of IPK

Full details of the content of the framework are to be reported at a later date once evaluation and validation has taken place.

3. Taking a Social Media Approach

As previously discussed, capturing an IPK object consists of an informal communication alongside the associated artefact to which it pertains, or a representation thereof (i.e. image). It has been shown that social media techniques lend themselves to the capture of this type of information [Ellison et al., 2007]. This section presents a proposed model of the IPK object and the social media approach for the capture, management and sharing of IPK over the lifecycle.

3.1 IPK Object Model

Figure 4 shows the proposed IPK object model and the collaborative tagging mechanisms that are being employed. The data model has been split into four sections that correspond to the IPK object model. These sections are described individually with regards to how the classifications from the framework are going to be used to tag the IPK. The tags created upon initiation provide a multi-faceted classification that can be used for search and retrieval purposes. As previously mentioned, IPKs demonstrate no pre-defined structure and thus an IPK can be considered a separate entity with no dependency on other IPKs. Thus, they can be considered analogous to tweets within Twitter. However, the development of the framework has indicated that a number of possible links could be made to create a network within the IPKs being stored. As these links are not always present in every IPK and may occur during at any time the evolution and re-use of an IPK, collaborative tagging has been proposed as a method to form these links. It is argued that creating these links will aid traceability, enable greater perspectives to be taken and aid the sender/receivership of the right IPKs to the right engineers.

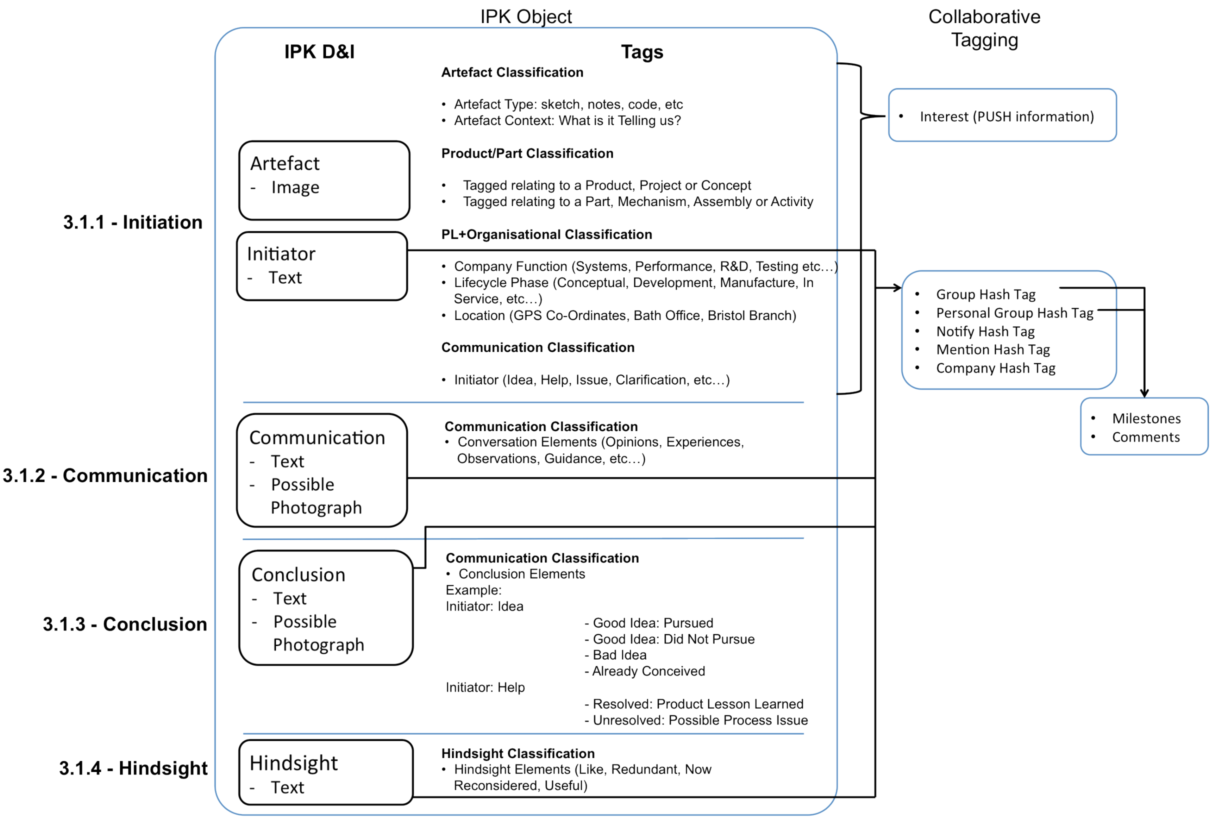

Figure 4: IPK Object Model and Collaborative Methods for Managing and Sharing IPK

3.1.1 Initiation

The initiation of an IPK contains tags from four classifications within the framework. The system requires the user to upload an image and message (i.e. text) and to tag it appropriately.

The Artefact Classification (1) focuses on the type of artefact being displayed within the image. It is suggested that two tags are required for the artefact. The first, determines the type of artefact that is being captured and the second, classifies what the artefact is trying to tell us. In both cases, multiple levels may be required to achieve the necessary granularity.

The Product/Part Classification (2) aims at determining the appropriate level of product perspective to the IPK. Once again, the level of detail required is to be considered and influencing factors may be the level of complexity of the product, the usability of the system being developed and the companies' current processes, for example. The language used for the naming of the part and product is also an area of interest. The companies' internal terminology and code structure, marketing terminology, and the colloquiums used by engineers to describe the product may influence the language used. Finally, the use of synonyms to bridge the gap between languages is also a possibility.

The PL+Organisational (3) Classification has been produced to capture the location of the IPK in relation to the PL and/or organisational structure. The initial review has suggested three areas to consider: *Organisational Function* (e.g. the Performance Team or Systems Team), *Lifecycle Phase* (e.g. Conceptual, Detailed Design, Manufacture & In-Service Phase) and *Physical Location*. Factors influencing the decision on the use of these are the company size/structure, collaboration between multiple partners, and the type of product being produced. Once again, language will play an important role in determining these classifications.

The final classification is the Communication Classification (4), which aims at following the evolution of the communication through the evolution of the IPK and to provide understanding to the text being written by the user. For the initiation phase, the tag determines the type of communication that is being produced (such as an engineer *expressing an idea* or highlighting a *possible issue*). All the tags produced from these classifications create the multi-faceted search and retrieval element for the IPK.

3.1.2 Communication

The communication section of the IPK object model requires users to tag their response text and images with the relevant type of response. This capture of the response type enables engineers to understand the perspective of other engineers and could be used to later understand the type of perspectives on which engineers' base their decisions and conclusions. Example response types are *opinions*, *experience*, *observations* and *guidance*. The types of response are subject to the type of initiator used at the start of the communication. In addition, the communication section allows multi-threaded communications to develop by necessitating the engineer to indicate to which part of the communication they are responding. The purpose of this is to allow divergence and breakdown of the initiators that are being posed (for example, breaking down a problem to more manageable pieces).

3.1.3 Conclusion

The conclusion section closes the real-time communication of the IPK object and in effect archives the IPK. The text and ability to upload an image enables the engineer to detail the results of the IPK generated and to demonstrate the output by means of an artefact. The creator is the sole person who can conclude the IPK (e.g. when their question has been *answered* or problem has been *solved*). The communication classification requires a tag to determine the outcome of the communication within the IPK. The tags available are subject to the type of initiator used.

3.1.4 Hindsight

The final section is hindsight and this enables engineers to comment on past IPKs. This uses the Hindsight Classification to determine the type of hindsight being made such as, *amendment, redundant* and *re-used*. Understanding the types of comment being made enables analysis of the potential re-use value of the IPK and could be used in the management of the IPK dataset.

3.2 Collaborative Tagging Mechanisms

As there is no pre-defined hierarchical or relational structuring between IPKs, collaborative tagging has been proposed for the generation of networks between the IPKs. Three examples are shown.

3.2.1 Group – Hash Tag

The *group* hash tag can be placed by any engineer contributing to an IPK at any stage of the process. Hash tags have been used in social media systems such as Twitter and are commonly placed within the text with a symbol placed in front that denotes its existence (e.g. *#group*). The aim is to group IPKs together using this tag and multiple group tags can be assigned to any one IPK, thereby enabling the IPK to be used/re-used in many different scenarios. Examples could be the grouping of IPKs for a specific task (i.e. *#Overview of Important Lessons Learned*) where human interpretation is required (i.e. Important). In addition, groups could be used for engineering groups (i.e. *#Bearing Experts*). This enables IPKs that may be relevant to a group of engineers to be highlighted.

Also, a comment section is provided as it has been noted in the current review that in some cases, engineers may wish to comment on the IPKs as a whole group and it can be seen logical when there are multiple users contributing to groups of IPKs that they will require the ability to discuss the group as a whole. Group tags can also be added to this comment section and thereby enable groups of IPKs and groups, or groups of groups, to be created. This may prove useful by providing an additional level of abstraction and could be seen useful for engineers considering *'Lessons Learned across the entire PL'* for example.

3.2.2 Mention – Hash Tag

The *mention* tag provides the ability for an engineer to add a link to another IPK within the system. This can be used throughout the IPK process. The aim is to provide traceability between IPKs within the system. An engineer may place a *mention* during a conversation element to highlight an IPK of interest or to add weight to their response (i.e. I feel that you need to consider this area as it was important in the past – *mention IPK 236*). Engineers using it during the conclusion of an IPK will provide the ability to show which IPKs were generated as a result of that IPK (i.e. We came to conclusion that we needed to look into – *mention IPK 32*, *mention IPK 435*). Finally, by using the tag in a hindsight element, engineers provide an insight into how future IPKs have resulted in the review of past IPKs (i.e. I looked at this IPK and needed to discuss this – *mention IPK 784*).

3.2.3 Interest

Interest provides the ability for the engineer to save a combination of tags that they wish to receive notifications upon, thereby presenting the idea of being *'interested'* in a particular aspect of the dataset. The saved combination allows the system to be pro-active rather than relying on an engineer to conduct a search. Using *interests* is critical in ensuring the right information is being received by the right engineers, especially for a system that will be storing a wealth of IPKs that can differ hugely due to the tags chosen from the classifications. Allowing a combination of tags enables the *interest* to be as specific or as general as the engineer wishes. In addition, engineers will have the ability to have multiple interests.

4. Demonstrator System - PartBook

To demonstrate the underlying framework, IPK object model and approach taken for the capture, management and sharing of IPK, a demonstrator system is currently in development. PartBook™ is the instantiation of the aforementioned framework, IPK object model and approach within a web and mobile app based environment. A brief discussion of the architecture and an example case of the generation of an IPK is shown.

4.1 Architecture

PartBook™ is developed to utilise both web and mobile app environments (Figure 5). All the information is stored within a MySQL database, apart from the images, which are stored within file directories and then referenced from within the database. Hypertext Pre-processor (PHP) is the language used to provide all the communications between the website/app to the database and enables the dynamic retrieval of information. Either the HTML5, JavaScript or iOS languages receive this information and produce the display for the user. Partbook™ provides a universal, platform neutral, format neutral and extensible environment for the capture, management and sharing of IPKs.

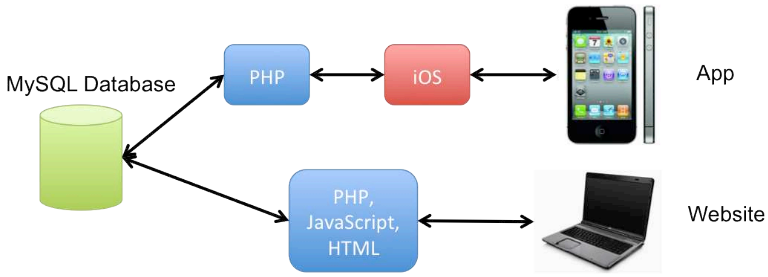

Figure 5: PartBook Architecture

4.2 Example Case

Figure 6 demonstrates through screenshots, the initiation of an IPK within the system. Part (a) shows the initial screen that the user is presented with upon the creation of a new IPK and the user is required to complete all the fields presented (b). These represent the tags produced from the classifications used in the capture of IPK. To conform to an IPK, the user is required to provide an artefact and for the case of the app environment presented here, the user selects *'post pic'*, which presents the user with the camera functionality to take a picture (c). Once completed, the IPK is then sent and stored within the database (d). The user can return to the 'my IPK' screen and the IPK is retrieved from the database (e), selecting the row enters the user into the communication feed for the IPK (f).

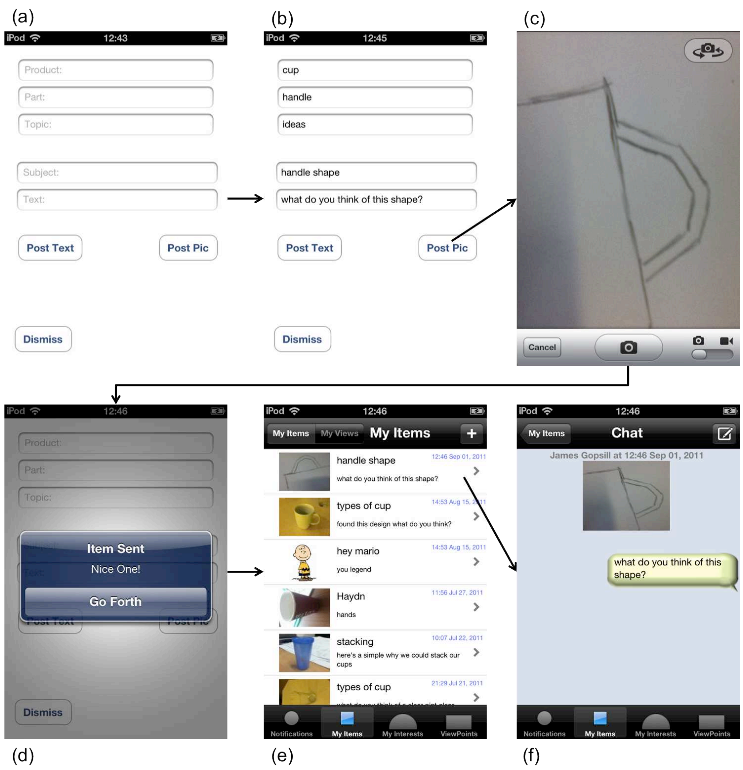

Figure 6: IPK Creation in App Environment

Figure 7 shows the function of the group hash tag (*#demo* – in this case) and the ability to comment within groups and have groups linked with IPKs and groups. This provides an easy method to navigate around IPKs as well as being able to discuss all the IPKs as a whole.

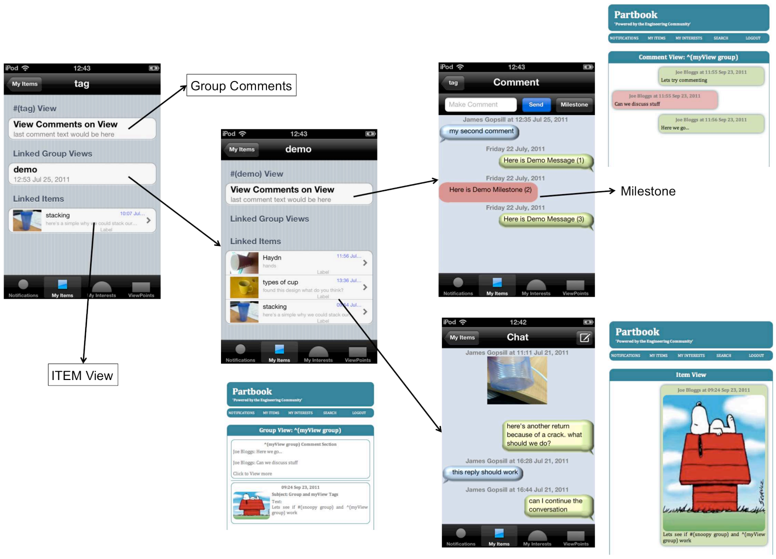

Figure 7: Development of Links through Group – Hash Tag (#*demo*)

6. Conclusion

This paper discusses the capture, management and sharing of Informal Product Knowledge (IPK). The IPK gap within the Product Lifecycle (PL) has been discussed and the potential benefits for capturing, managing and sharing IPK described. To address this challenge, the paper discusses the underlying framework that is currently being developed to capture, manage and share IPK. The need to capture the engineering context is discussed, highlighting five key areas of the framework, which include the (i) Artefact Classification, (ii) Product/Part & PL+Organisational Classification, (iii) Communication Classification, (iv) Managing and Sharing Criteria and (v) Hindsight Classification. To evaluate and validate the framework, this paper presents an IPK object model and social media approach that describes how an IPK is to be captured, managed and shared through several tagging classifications and collaborative tagging mechanisms. This approach has been incorporated within a demonstrator system known as PartBook™, which the authors are currently using to understand the generation and evolution of IPK through an undergraduate design project.

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